

HYDROGEN PROGRAMS AT SAVANNAH RIVER SITE

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Savannah River Technology Center

April 29, 2003

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OUTLINE

- **DOE Savannah River Site**
- **Hydrogen Technology Laboratory at SRS**
- **R&D Programs**
- **Hydrogen Projects & Demos**
- **Nuclear Hydrogen Production**

The logo for the Savannah River Site (SRS) features the letters "SRS" in a bold, black, sans-serif font. To the left of the text is a stylized graphic consisting of two overlapping, curved lines that form a partial circle or 'C' shape, rendered in a dark color.

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Savannah River Site Aiken, South Carolina

- DOE site, operated and managed by the Westinghouse Savannah River Co.
- Started in 1950 as part of U.S. Nuclear Defense Complex
- Located near Aiken, SC; occupies 310 sq. miles and has 14,000 employees
- Primary mission is Nuclear Waste Mgmt. and Defense Material Production
- Tritium and hydrogen handling since 1955; lead site for future tritium missions
- Applied R&D provided by Savannah River Technology Center (DOE Federal Laboratory; over 750 employees)



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DOE's Savannah River Site

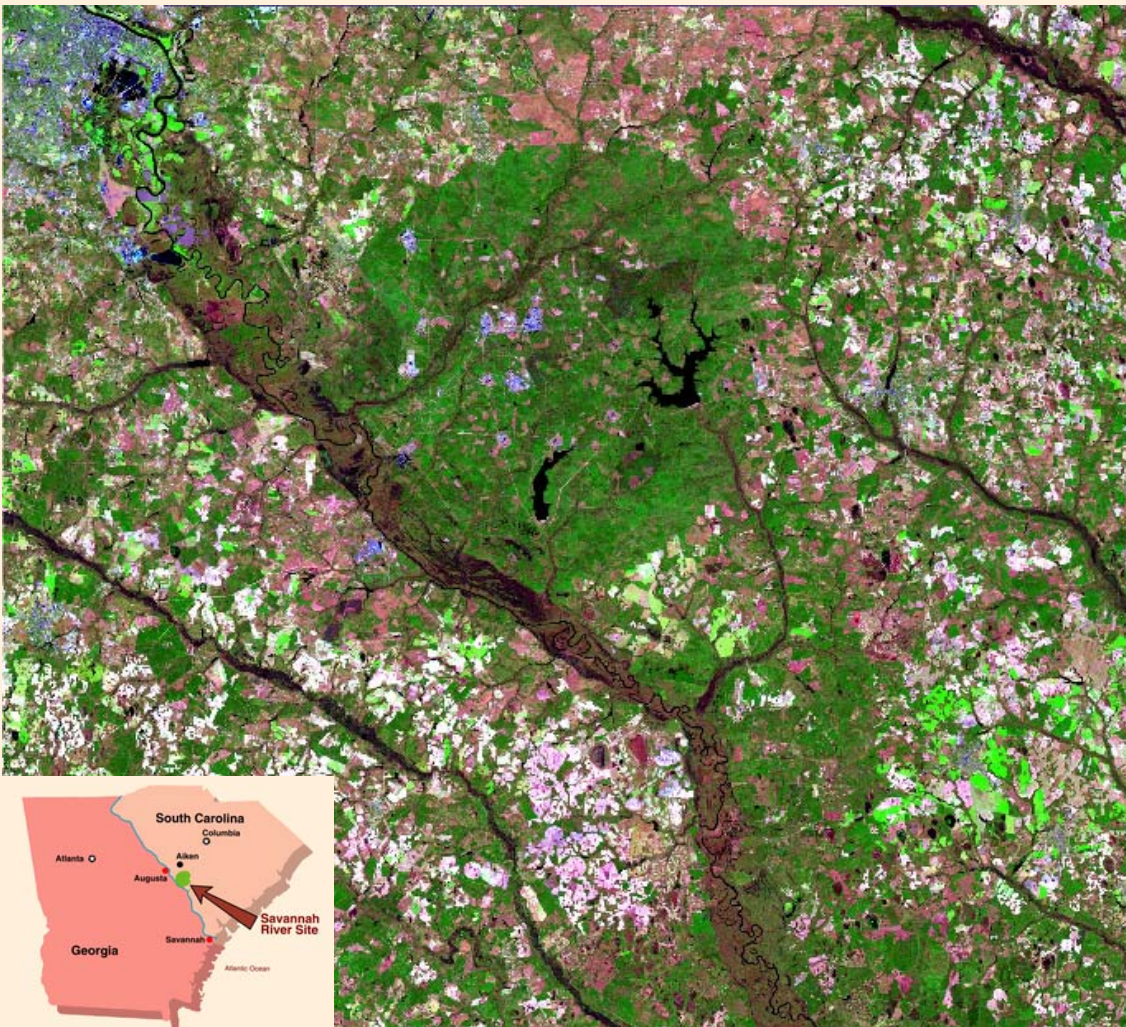


Image of SRS taken by the Landsat Satellite in 1999.

- Forested Areas
- Urban Areas
- } Agricultural Areas
- }
- }

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Savannah River Technology Center

- Operations Support and Analysis
- Applied R & D
- Real Time/ Real Problem Solvers
- Customer (Operations) Influenced
- Conduit for Solving DOE Complex Problems



**Technology
Need**



**Solution
Concept**



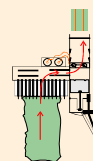
Develop



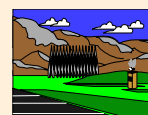
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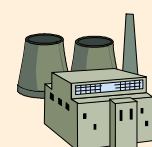
Test



Pilot



Field



Startup



Plant Support

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“More than a Research Laboratory”

Core and Enabling Technologies

Key Enabling Technologies

- Analytical Chemistry
- Computation, Modeling, and Statistics
- Materials Technologies

SRTC Integration

Core Technologies

- Waste Processing
- Remote Systems
- Environmental Remediation
- **Tritium/Hydrogen**
- Non-Proliferation Technology and National Security
- Instruments and Sensors
- Actinide Processing
- Aluminum Reactor Fuel

SRTC Line Integration

Integration with Plant Engineering and Operations

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University Collaborations

SCOREF

- Clemson University
- University of South Carolina
- Medical University of South Carolina
- South Carolina State University

ERDA

- Georgia Institute of Technology
- University of Georgia
- Medical College of Georgia
- Emory
- Georgia State
- Clark Atlanta

Other Universities

- University of Florida
- Florida International University
- Mississippi State University
- University of Minnesota
- University of Memphis
- Miami University
- Colorado State University
- University of Alabama - Huntsville
- Florida A&M University
- Oregon State University
- Virginia Polytechnic Institute
- Augusta State University
- Paine College

HyTech Laboratory

- **HyTech is the Hydrogen Technology Laboratory at Savannah River Site**
- **HyTech is comprised of >80 scientists, engineers, and analysts focused on hydrogen technology development**
- **HyTech is part of the Savannah River Technology Center, DOE Federal Laboratory, with over 750 employees**
- **Mission: Partner with industry, academia, and government to develop new hydrogen technology to address national energy needs and to maintain and enhance our core hydrogen technology capabilities.**

HyTech Technologies

■ Metal Hydrides

- ▶ storage
- ▶ compressors/pumps
- ▶ purifiers/separators
- ▶ heat pumps/refrigeration

■ Advanced H2 Storage

■ Battery / Fuel Cells

- ▶ Ni metal hydride
- ▶ catalysts

■ Sensors

- ▶ fiber optic & composite

■ Hydrogen Production

- ▶ Pd/ceramic membranes
- ▶ nuclear hydrogen

■ Materials Compatibility

- ▶ H2 embrittlement
- ▶ failure analyses

■ Safety (WSMS)

- ▶ H2 safety analyses
- ▶ codes and standards
- ▶ testing

Current HyTech Programs

Research and Development

- Sol-gel MH and membrane filters for H₂ separation
- Advanced hydrogen storage materials
- Doped carbon nanotubes
- Storage vessel design and optimization

Demonstration Projects

- H₂Fuel Bus
- Industrial Fuel Cell Vehicle Program
- Fuel Cell/Metal Hydride Mining Vehicle Program
- Nuclear Hydrogen Production Analysis

Sol-Gel MH Objectives

- **Develop an efficient hydrogen separation process to purify hydrogen from other gases:**
 - ▶ **Feed gas: hydrogen, hydrocarbons, carbon oxides, water vapor & air, low hydrogen concentration (<~50%)**
 - ▶ **Sol-gel encapsulated metal hydride that selectively absorbs hydrogen and resists the adverse effects of reactive impurities (O₂, CO)**
 - ▶ **Thermal swing absorption process**

Sol-gel Encapsulated Metal Hydride Production

Wet sol-gel encapsulated metal hydride



Hydrogen separation test column

Sol-gel encapsulated metal hydride, dried and ground

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Advanced Metal Hydrides

Development Path

- La-Ni Alloys
- Fe-Ti Alloys
- Ca-Mg Alloys
- Na-Al (Alanates)



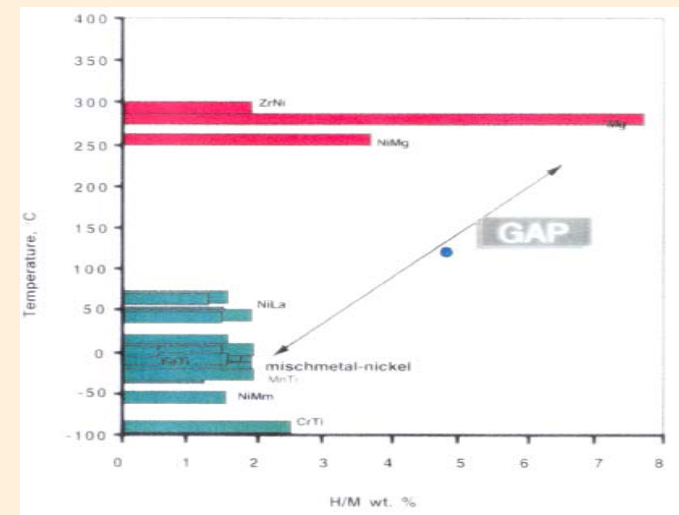
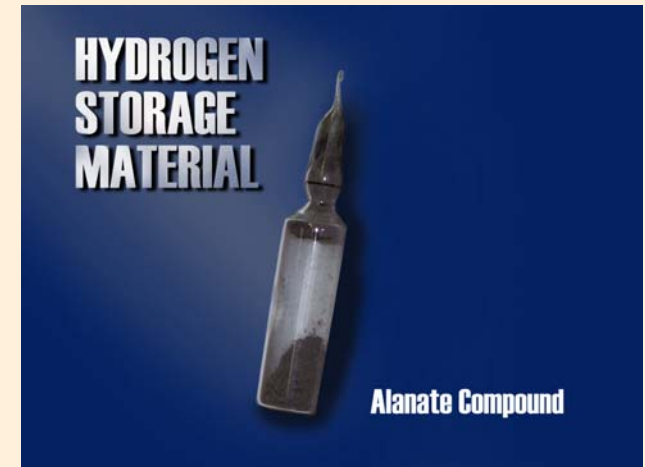
bulk metal hydride material



crushed and sieved metal hydride

Pioneering R&D on Alanates

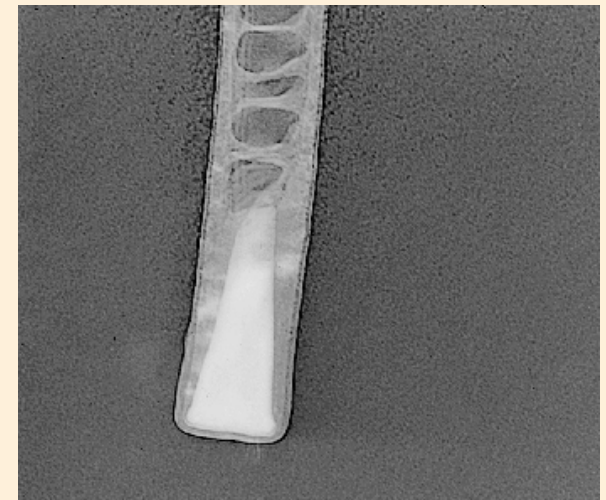
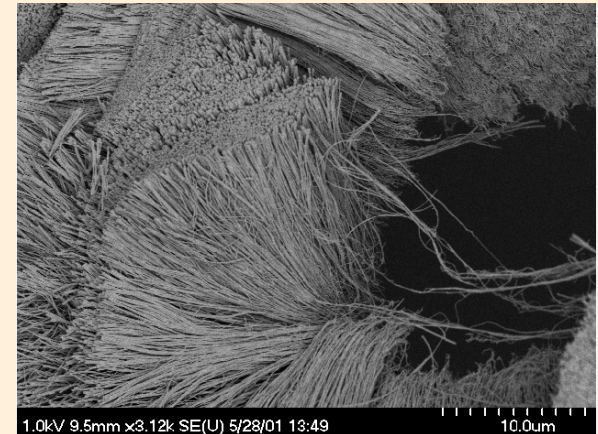
- CRADA with United Technology & partnering with USC
- Lead PI holds one of fundamental alanate patents
- Have collaborated with other leading scientists in the field including high energy neutron diffraction work at Grenoble
- Participating in IEA and DOE working groups
- New formation/doping method (patent applied)



Hydrogen Storage on Carbon Nanotubes

R&D Activities

- ▶ high risk - high reward R&D
- ▶ working with Clemson, USC and others
- ▶ identified method of producing large quantities of single and multi-wall nanotubes (CVD)
- ▶ demonstrated method of doping nanotubes with metal and metal alloys
- ▶ preliminary experimental results show hydrogen storage potential
- ▶ patent applied



Carbon Nanotube

SRTC Hydrogen Projects

- **H2Fuel Bus**
- **Industrial Fuel Cell Vehicle Program**
- **Fuel Cell/Metal Hydride Mining Vehicles**
- **Nuclear Hydrogen Production Analysis**

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H2Fuel Bus



**World's first Hydrogen Hybrid
Electric Bus (Augusta, GA)**



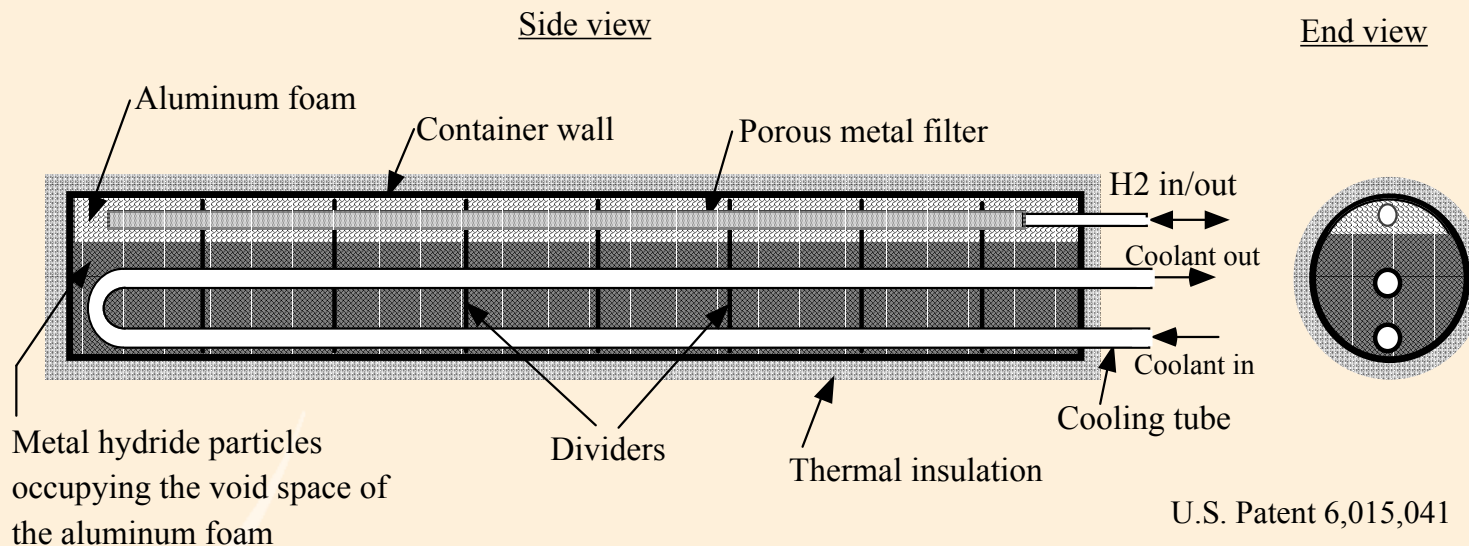
**World's largest mobile metal
hydride storage bed**

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SRTC's Hydrogen Storage Device

- High performance tubular design permits compact storage and rapid refueling
- Modular concept adaptable to various applications



Industrial Fuel Cell Vehicle Program

- Goal: develop a fuel cell vehicle with onboard MH storage for near term niche markets (airports, warehouses, etc.).
- Demo Phase from 10/98 - 1/01
- Funding - \$1.2M
- Partners: John Deere, Energy Partners, Teledyne Brown, USC, York Tech, Southeastern Tech Center, DOE-EE.



WHEC, Montreal, June 2002

“Gator” Fuel Cell Vehicle

- Potential applications:
 - airports
 - warehouses
 - lawn care, etc.



- Advantages:
 - zero emissions
 - same performance as gasoline vehicle
 - outperforms battery vehicle



Fuel Cell Vehicle with onboard metal hydride vessel



One of Two SRS metal hydride vessels for fuel cell vehicle

Mining and Large Industrial Hydrogen Demonstrations



Underground Mining Loader



H2-ICE Truck w/MHStorage



Fuel Cell Locomotive for US Army



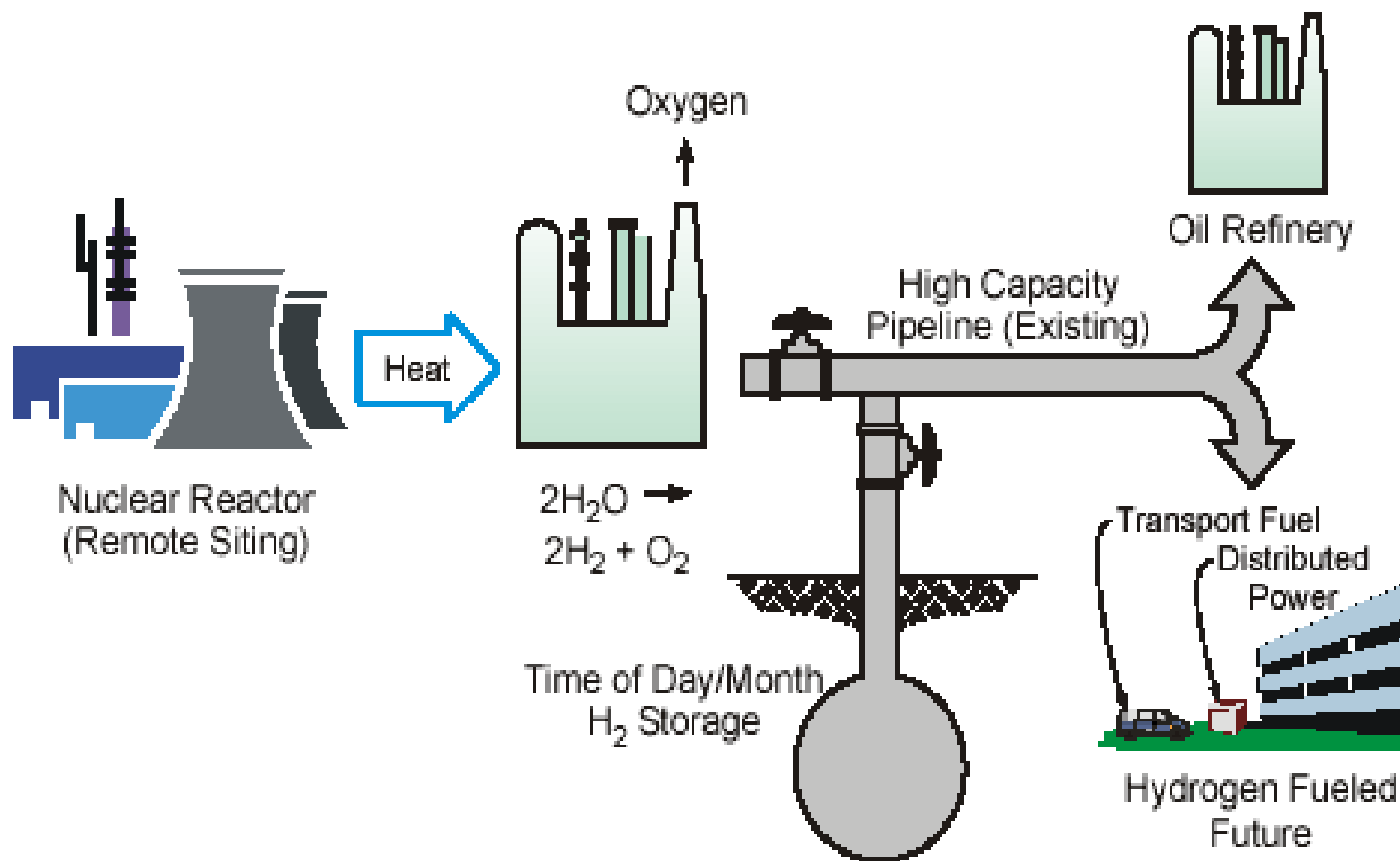
Fuel Cell Mining Locomotive

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Nuclear-Hydrogen Future



Source: C. Forsberg, ORNL

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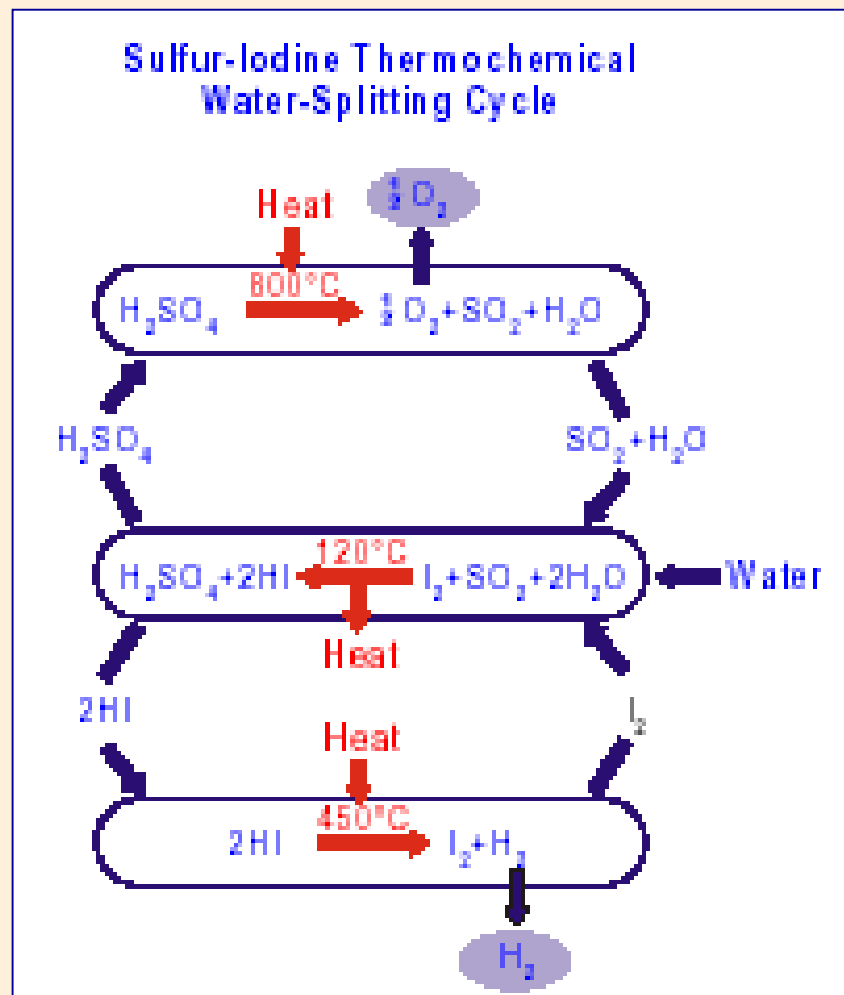
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NERI Infrastructure Analysis and Design Study

- **SRTC-led team awarded three-year study by
DOE Nuclear Energy Research Initiative (NERI)**
- **Partners:**
 - ▶ **General Atomics, Entergy Nuclear Inc., Argonne
National Lab, USC, key consultants**
- **Phase I - Nu-H2 Infrastructure Analysis**
 - ▶ **Assess key technical and economic issues**
- **Phase II - Test Case Pre-conceptual Design**
 - ▶ **Prototype Nu-H2 Plant at SRS integrated with local
hydrogen user (chemical plant)**

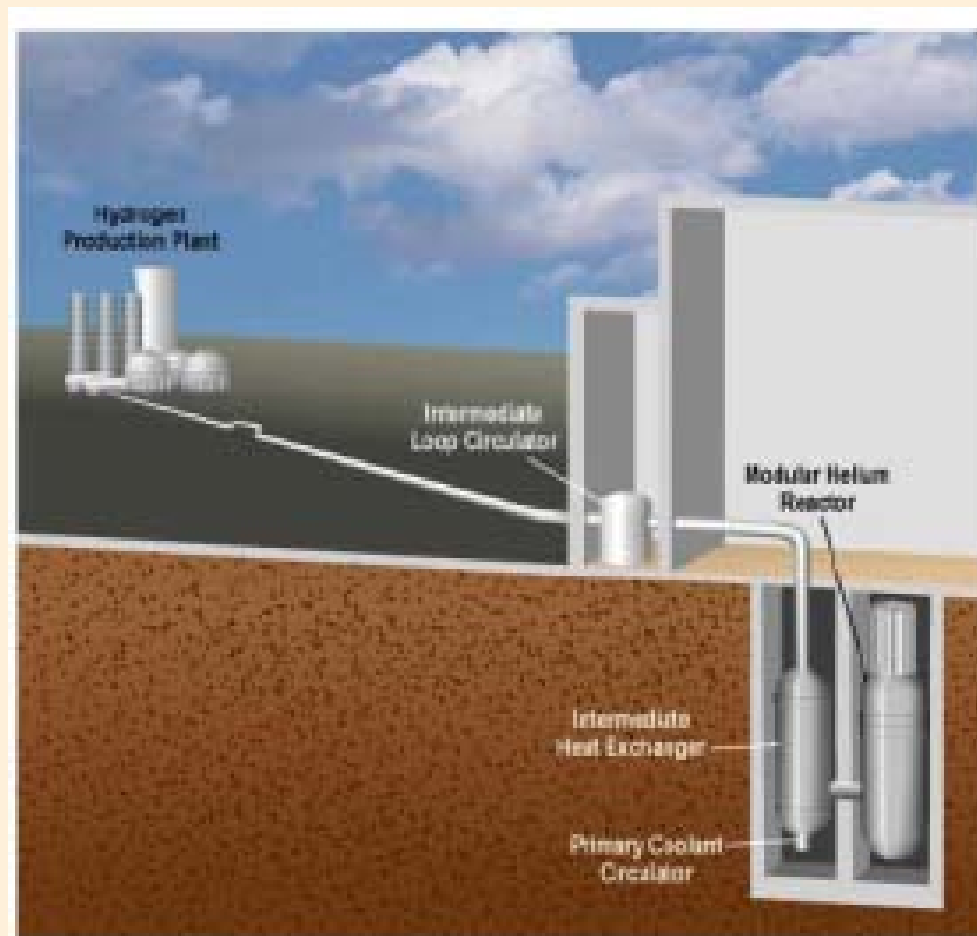
Thermochemical Hydrogen Production

- Use of high temperature heat to split water molecules
- Extensively studied in 1970s
- Requires 800-900 °C heat input (Carnot-like efficiency)
- Lab-scale development stage
- Two leading cycles:
 - ▶ Sulfur-Iodine Process (S-I)
 - ▶ Japanese UT-3 (Ca-Br-Fe)



Advanced Reactors are a Good Match for Hydrogen Production

- **Modular Design**
- **Inherent Safety**
- **High Temperature**
(>850 C outlet)
- **Favorable Economics**
- **High Efficiency**
- **Comparable Market Timing**

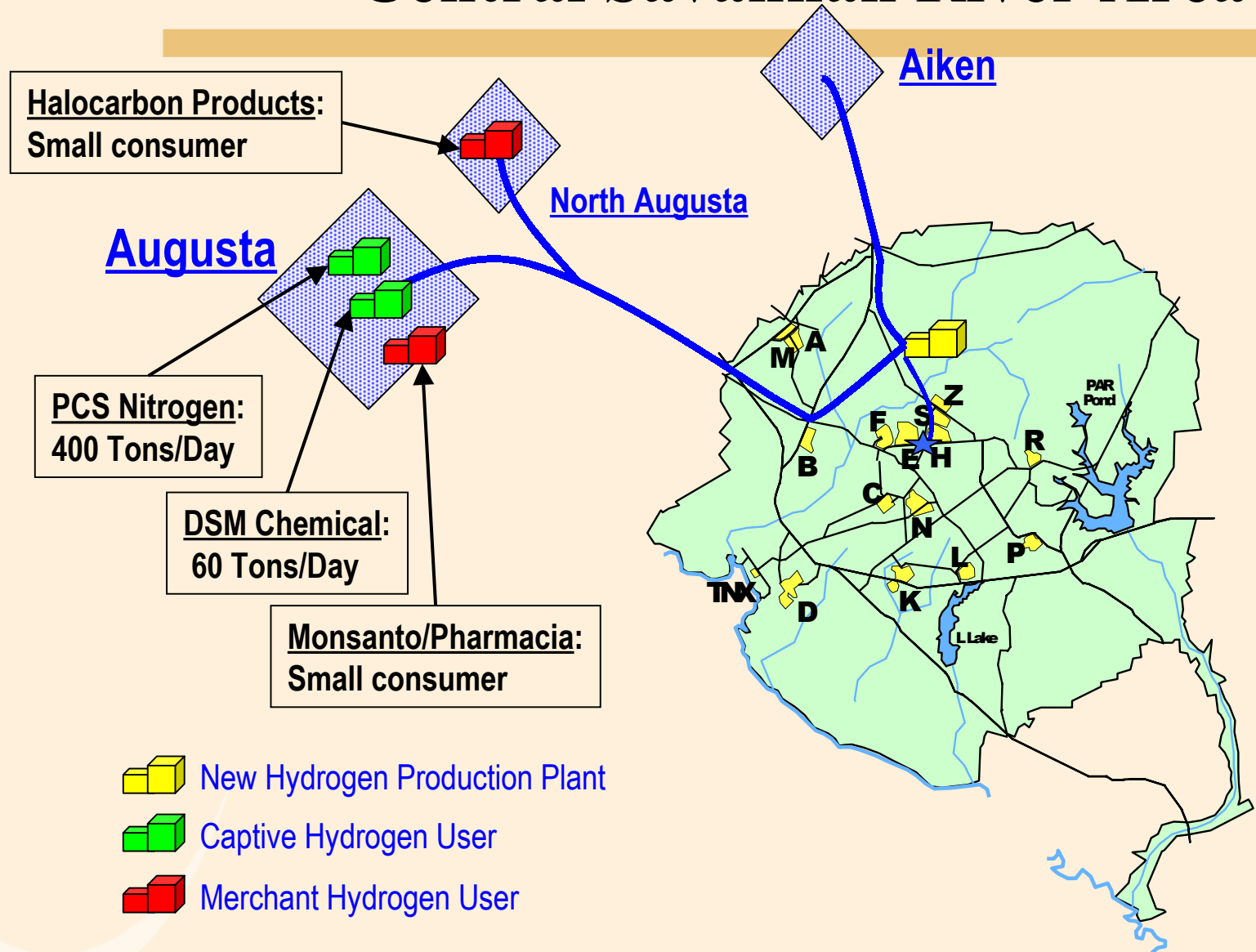


H₂-MHR

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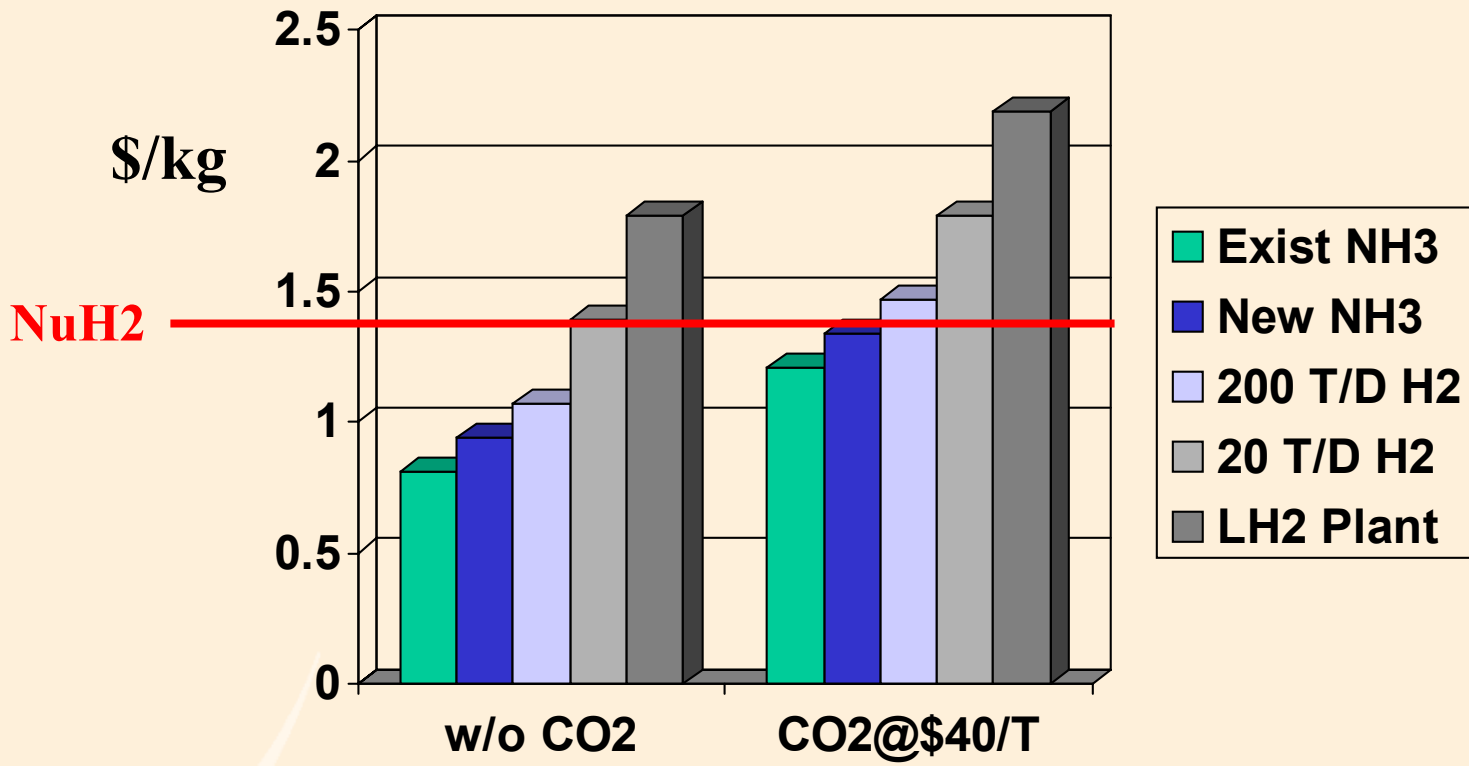
Hydrogen Users in the Central Savannah River Area



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Initial Economic Results Appear Promising

Hydrogen Production Costs w/ \$5 per MMBtu Natural Gas



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Summary

- **Hydrogen is the “Fuel of the Future”**
- **Savannah River Site has a long and ongoing hydrogen mission for national defense**
- **SRS is working with world-class partners to address the key issues & challenges of a hydrogen energy economy**
- **South Carolina can help lead the nation in transitioning to a secure, clean hydrogen future**

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